Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.6, No.19, 2016
www.iiste.org

# Gonadal Developments of West African Freshwater Crab (Sudanonautes Africanus, Milne–Edwards, 1869) on the Banks of Asejire Reservoir, Nigeria

M. O. Sodamola[1*] O. A. Bello-Olusoji[2] Y.A Adejola[1]
1. Department of Animal Production and Technology, Federal College of Agriculture, Moor Plantation, Apata, Ibadan, Nigeria
2. Department of Fisheries and Wildlife, Federal University of Technology, P. M. B 704, Akure, Nigeria

**Abstract**
This paper was on the developmental changes that take place inside the eggs of the fresh water crab (*Sudanonuates africanus*) from Asejire reservoir in Ibadan Nigerian. The egg consist of two layers a thick outer membrane and a thin inner membrane that encloses the fluid- filled embryonic sac. Development in this species took up to 77 days, after which the free- living juvenile hatching crab emerged from the egg. During developmental the embryo underwent a series of morphological changes that corresponded to the free living larval stages of marine crabs and the yolk mass decreased in size and changed color (from yellow, to orange brown and finally off- white) the eggs remained attached to the pleopods in the females abdominal brood pouch during development and showed a great deal of independence from water embryos developed normally whether they were immersed in water or in air.
**Keywords:** Crab, Egg, Fecundity, Fresh water, Gonads

## INRODUCTION

Arthropoda is the largest and most diverse animal phylum. It includes insects and crustacean members are distinguished by an exoskeleton that is periodically shed to make room for growth known as molting. The body is segmented and bear paired jointed appendages. The most popular body segmentation is into three segments the head, thorax and abdomen. Crustacean is a successful class of arthropods in terms of both number of living species and colonization of different habitats. Their habitats include the deep oceans, coastal estuarine regions, semi terrestrial, terrestrial and freshwater environments of ponds and lakes (Ruiz *et al.,* 1993). Crustaceans are primarily aquatic arthropods.

The popular and largest crustaceans belong to the order decapoda which include shrimps, lobsters, prawns and crayfish. Brachyurans are the most advanced of the decapods this represents the true crab genus further divided into two families. Oxyrhyncha species are marine crabs and branchyncha species are freshwater crabs.

Freshwater crab lives on land in burrow and under what can cover them well. They are active at night (Cumberlidge, 1999). There are primarily vegetarian and scavengers, and can run very fast, with eyes are well developed to see from distance and very sensitive to the environment. Freshwater crabs were originally known as river crabs and were given family names such as Thelphusidae and Potamonidae, the latter name derived from the Greek word freshwater crabs are mostly found in burrow made by them as a house to escape from predators (Grimes *et al*., 1989). Freshwater crabs demonstrate a broad range of habitat preference (Yeo *et al*., 2008, Cumberlidge *et al*., 2009) Many species of true freshwater crab are fully aquatic and spend their entire life cycle in water ( Liu and Li, 2000). They live most of their lives in water (Ng and Naiyanetr, 1995, 1998). And hide under stones on the stream bed during the day and forages either in the stream or on land at night. The West African freshwater crab belong to the family Potamonutidae are hardy, with over 88 species present in the streams and river systems across Africa (Cumberlidge, 1999). Potamonutidae crabs are found in large number in nearly all the available freshwater bodies in Nigeria, but they are underutilized except for local consumption (Bello–Olusoji *et al.,* 2010). *S. africanus* is a common, brachyuran, freshwater crab that is widely distributed throughout Nigeria, Central Africa, South Africa, Cameroun, Congo, Gabon and Zaire (Cumberlidge, 1999). These work focus on the development of gonad and fertilizd eggs of *S. africanus* a common species of freshwater crab found in and around the Asejire reservoir, Nigeria. This species hides under stones on the reservoir bed and mud. Females carrying between 80- 120 eggs move into shallow water during the early breeding season and typically feed on land at night

*S. africanus* was selected to investigate changes that occur inside the developing embryos.

## MATERIALS AND METHODS

### STUDY AREA

This study was carried out on the banks of Asejire reservoir in Egbeda Local Government Area of Oyo State Southwestern Nigeria (Figure I). Egbeda Local Government is one of the 33 local government areas in Oyo State.

 

The reservoir took its source form Osun river and flows through Oluwo and Alaye- ala down to Asejire. The reservoir supplies water to the Ibadan and Osun municipality for domestic uses. Ibadan is the largest city in West Africa, with a high population of inhabitants cutting across people from different tribes which include Hausas, Igbo, Yoruba and Efiks etc.

The study area is located at the south-western part of Nigeria. It is a man-made reservoir. The reservoir is bi-focated with two unequal arms surrounded by large mass of land the left longer arm is fed by Rivers Oba and Oshun while the right arm is supplied by River Agboiro (Adebisi, 1981). The catchment area in the reservoir is 7800km$^2$ and the impounded area is 2,342 hectares. The reservoir has a normal pool elevation (water level) of 150m and maximum flood elevation of 152.4m. The reservoir has an approximate gross storage of 7,403 million litres. The construction of reservoir divides the fishing area into two main zones i.e. the upstream and the downstream (Ogunleye, 1982). It has a rainy season (April-October) with a monthly water mean of 10.3-15.9mm while dry season is between (November–March) with water mean of 3.78 – 4.2mm.

Asejire reservoir lies between longitudes 4$^E$ and 4$^0$07$^E$ and latitudes 7$^{0N}$ and 7$^0$21$^N$. The total area covered by the study area is about 10,000 hectares from Ibadan along Ibadan –Ife expressway, The reservoir flows approximately 5km from its source before breaking into series of rivers and streams (Anatekahi, 1997), with emerging 20 communities dispersed around the reservoir which traverse different settlements (Adebisi, 1981). The occupations of majority of the populace are trading, fishing and farming. For a longtime, traditional fishing has been known in this reservoir. About twenty –five species were identified in the reservoir by Ogunleye, (1982). Some of the commercial important fish and shell fish found include; *Heterobranchus*, *Hemichromis spp*, *longifilis*,*Clarias gariepinus*, *Clarias anguillaris*, *Oreochromis niloticus*, *Tilapia zillii*, *T. mariea*, *Macrobrauchium vollenhovennii* and *Sudannautes africanus.*

Crabs catch reaches the peak between April and September during the wet season when the reservoir water level is high and low catch is recorded from November to March during the dry season when the water level of the reservoir is low. The study area was selected based on the high activities of aquaculture and accessibility,

 

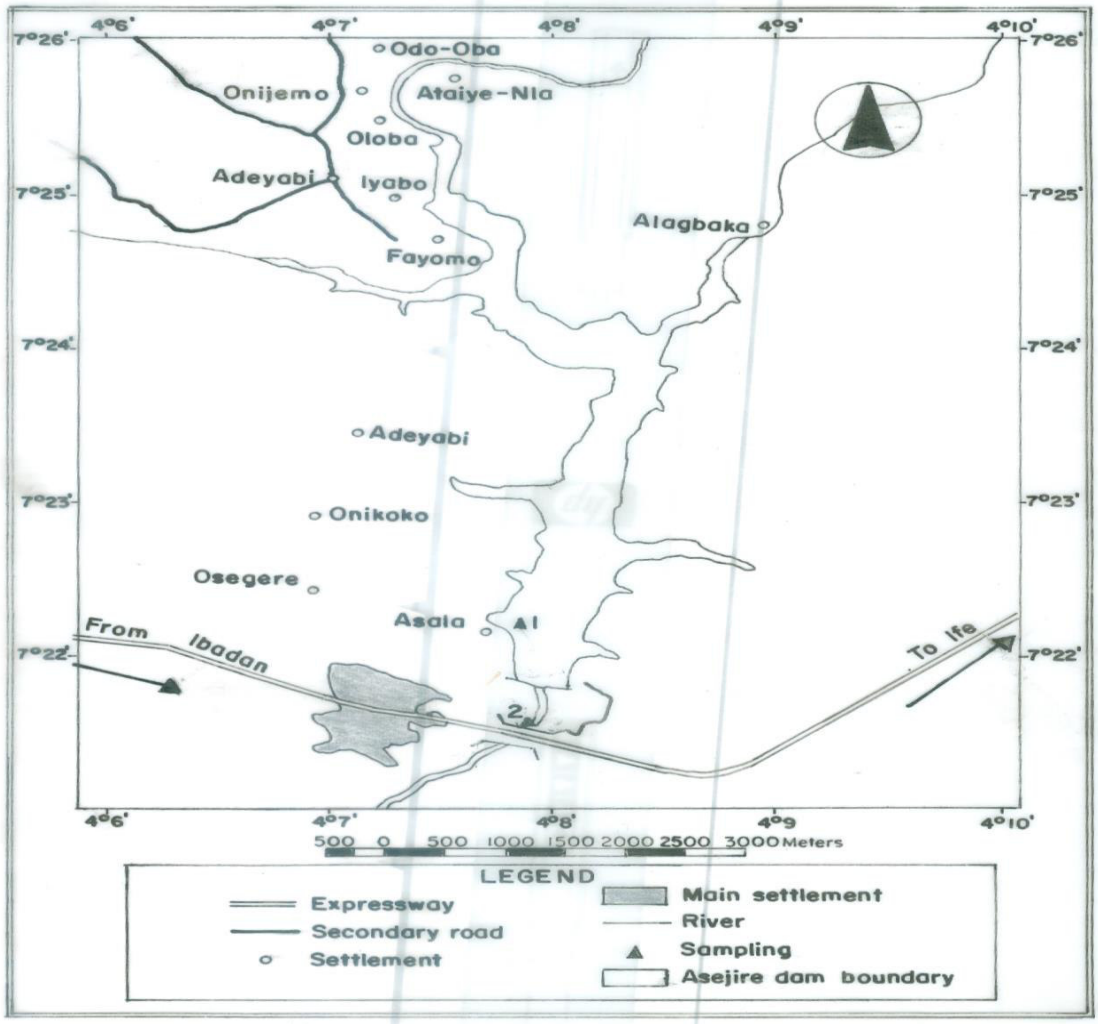


Fig. 3.1: Map of Asejre reservior showing the sampling areas

**Gonad Weight GW (g):** This was carried out by slit opening each crab pouch removing the gonad and weighing on Mettler digital balance. Fourty Freshwater crabs (*S. africanus)* were maintained in the laboratory in one plastic tank(0.50×0.30×0.35 m) supplied with shallow fresh water that did not completely immerse the crabs, and with a raised platform that allowed crabs to spend time out of water. The water was maintained at 25±1°C, leached with a water purifier (MF-1 Filter), and replaced every two days. Crabs were fed every evening with coconut and earthworms the female crabs were allowed to spawned, at which point they were separated and cultured in individual tank. Twenty ovigerous females were observed every day from spawning until hatching of the eggs. Crabs divided their time equally between periods of immersion in shallow water and periods when they were resting out of the water. Two to four eggs were removed daily at 9:00 am from each female and fixed in 70% ethanol for analysis. A scapel was used to with the careful peeling away of the developing embryos from the inner membrane, and the embryos were photographed using a digital camera fitted to the microscope.

**Gonadal Stages:** The stages of egg development were identified as described by Kennan *et al.,* (1998). Each specimen was kept in separate specimen bottle with a label bearing date caught and stage of gonad on each specimen bottle. The specimen bottle was shaken vigorously at 30 minutes intervals, to disengage the egg from the ovarian tissue and also for deeper penetration of formalin which serves as a preservative. The stages of the egg were observed by using five stages of egg development based on the colour as described by Cumberlidge, (1999).

| | | |
|---|---|---|
| Stage I | Immature | (yellow) |
| Stage II | Developing | (orange) |
| Stage III | Mature | (brown) |
| Stage IV | Ripe | (dark brown) |
| Stage V | spent | (off-white) |

 

### 3.6.5 Gonado-Somatic Index

$$GSI = \frac{Weight\ of\ ovaries}{weight\ of\ crab - Weight\ of\ ovary}$$

## RESULTS

Fertilized eggs were removed from the pleopods of the twenty ovigerous females of *S. africanus*, eggs were( 3.5-4.5mm diameter ), round, and a uniform creamy yellow color each embryo was found to be completely surrounded by a two layered membrane a thick outer membrane and a thinner inner membrane that formed a fluid – filled sac around. Newly laid eggs consisted almost entirely of creamy pale yellow yolk( plate 1)the developing embryo and yolk mass membrane and with a fluid – filled sac around the developing embryo and yolk mass. Later the yolk became dark yellow and a small fluid transparent sac (the inner membrane) was visible that contained a small white mass (the developing embryo) on one side of the egg ( plate 2) ( Wu *et al*., 2010) after 19 days the embryo was visible on one side of the sac as a large brown mass after 65days ( plate3) the yolk had changed color from brown to dark brown( which now had recognizable larval features such as compound eyes) and the fluid –filled sac . After 75 days the embryo had developed to a stage that resembled a juvenile crab (termed the egg juvenile crab by Wu *et al*., 2010) the embryo burst to release a free – living hatchling crab. The complete developmental process inside the egg case was therefore observed to take about 77 days from fertilized egg to free living hatchling crab.

**Table 1: Mean and Range for gravid *S. africanus* female on Asejire reservoir**

| | | |
|---|---|---|
| Mean | Length (cm) | 6.76 |
| | Weight (g) | 87.5 |
| | Fecundity | 292 |
| Range | Length (cm) | 7.5 – 14.5 |
| | Weight (g) | 80.5 – 165 |
| | Fecundity | 120-451 |

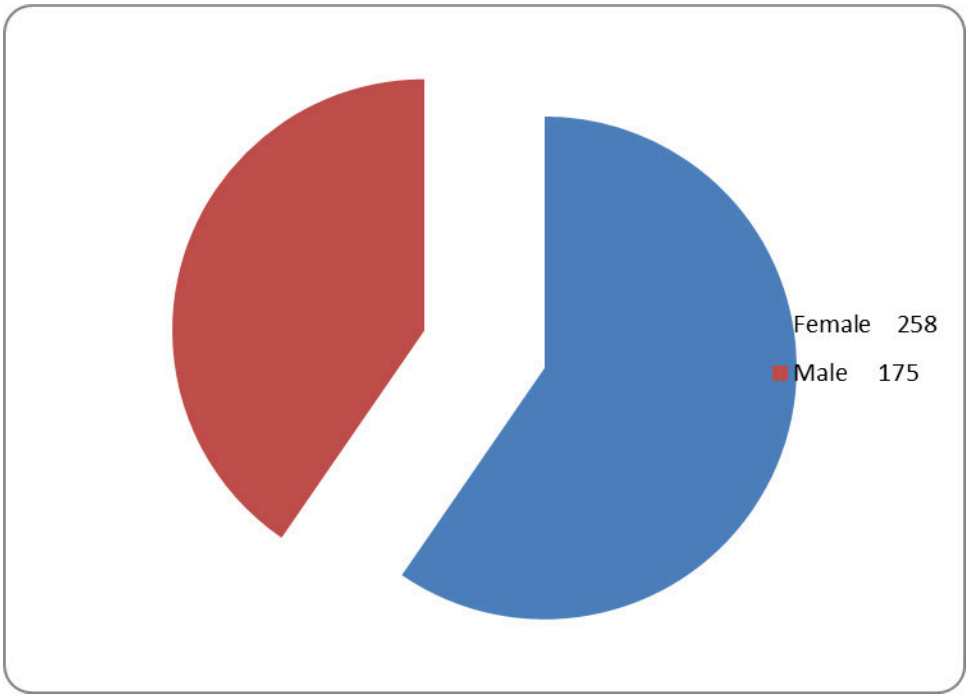


**Figure1**: Sex ratio of Male:Female *S.africanus* on banks of Asejire reservoir

Male and female *S. africanus* crabs were randomly collected and examined. A total number of 433 *S. africanus* freshwater crabs were collected in which 258 were females and 175 were males and the sex ratio was 3:2 (62% female and 38% male). It was observed that there were more females than males both in the wet and dry seasons.

 

**Plate 1: Developed stage of egg in *S. africanus* crab at bank of Asejire reservoir.**

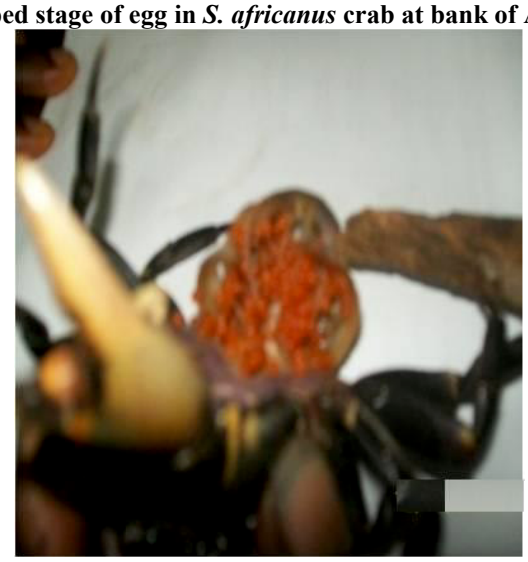

**Plate 2: Developing stage of egg in *S. africanus* crab at bank of Asejire reservoir.**

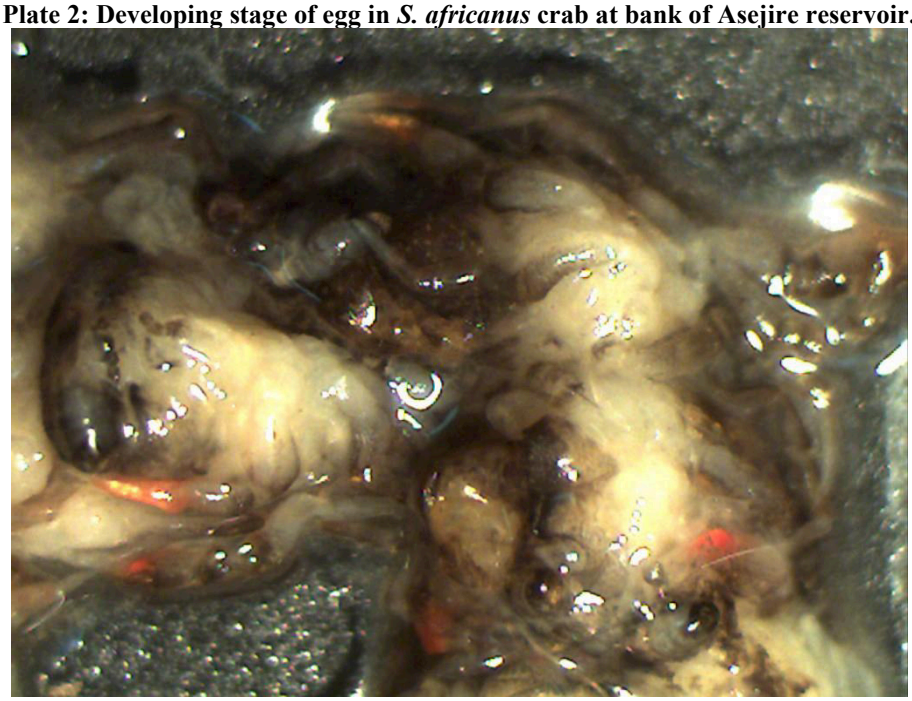

**Plate 3: Viewed under microscope, scale bar = 1mm**

 

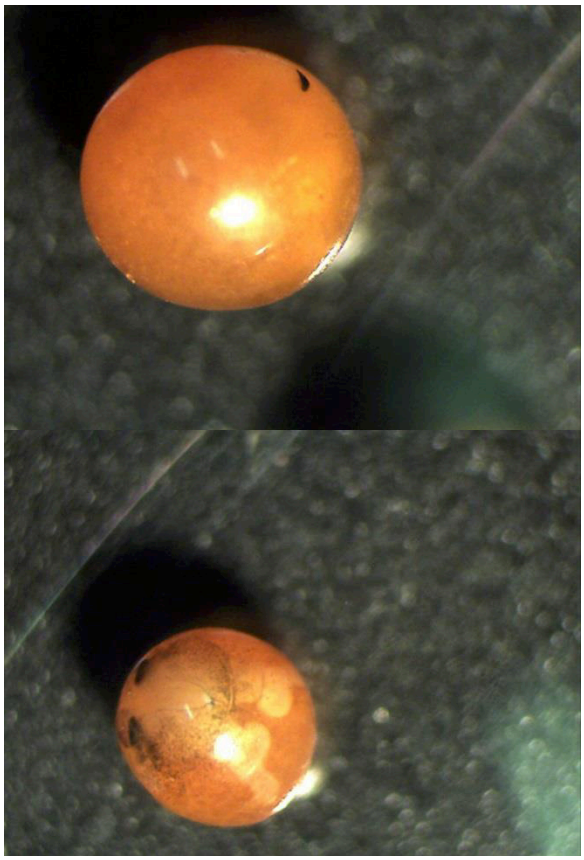

**Plate 4**
**Developmental changes inside eggs (from 13 – 19 days), Scale bar = 1mm**

**Plate 1a: Gravid female of *S. africanus* on Asejire reservoir**

 

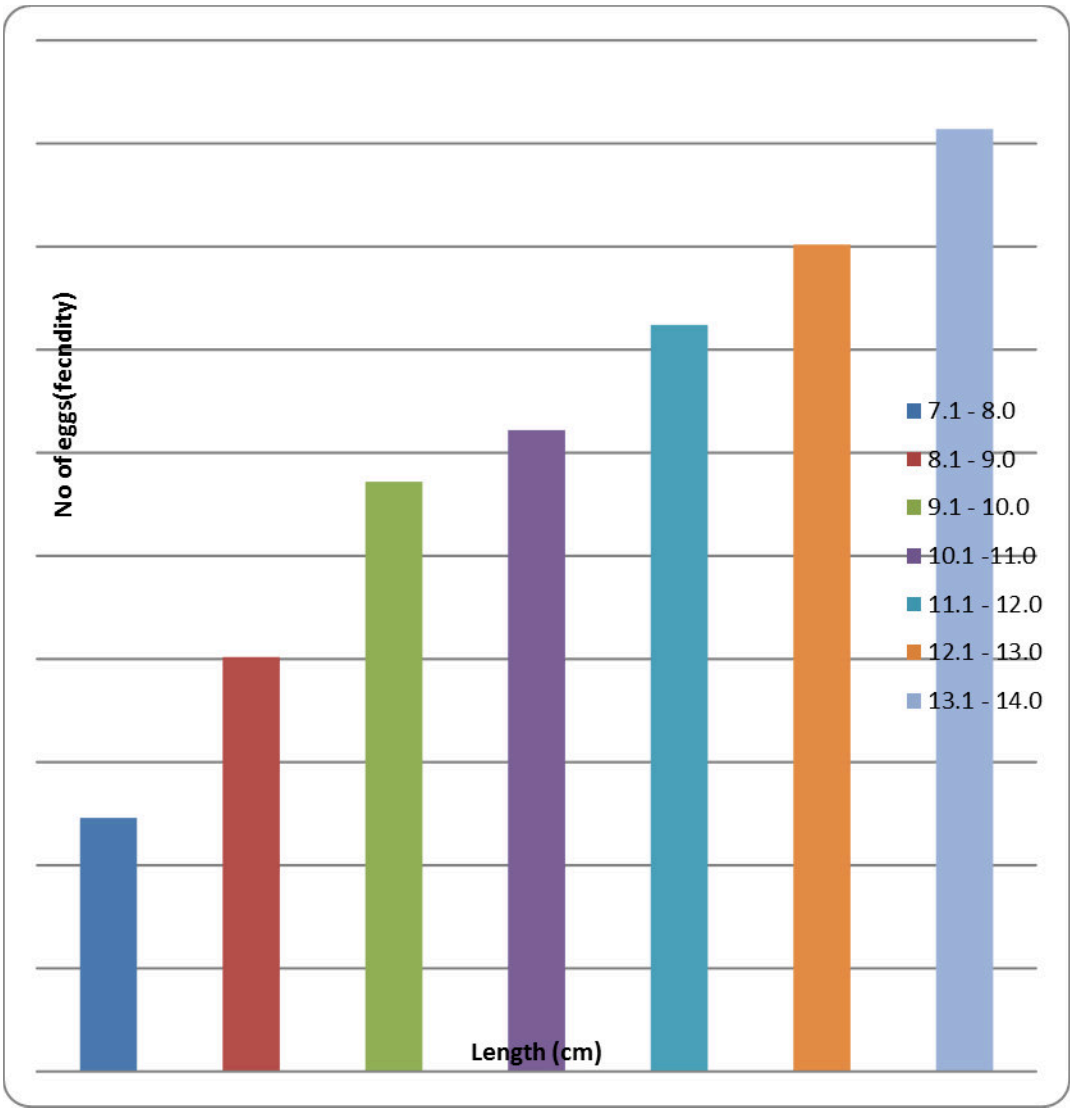


**Figure 2: Fecundity of *S. africanus* on banks of Asejire reservoir**

Gravid females were used for fecundity studies (Table 1 ). Result of fecundity showed that the number of eggs carried by crabs ranged from 120 to 451 with an average diameter of 1mm-2mm per egg and increased to between 3 to 4.5mm as they develop towards hatching. This indicates that gravid female of *S. africanus* lay up to half a thousand eggs. The result also indicates that female crabs with the highest fecundity (451eggs) was 12.5cm in length while the female crab with the lowest fecundity (120 eggs) was 6.5cm in length indicating that the number of eggs carried by matured female crabs depends on their size. This also implies that there is a relationship between the carapace length of the crabs and the number of egg carried.

This further shows that there is a strong correlation between the fecundity and the weight of the gravid crabs. As the gonads mature, there was change in the colour of egg, at every developmental stage from orange to yellow and finally to brown It was also observed that the female crab usually carry the newly hatched young ones in their chest (pleopods) for about (2-3weeeks). Plate 1-4 shows the different changes in color of egg from one developmental stage to the other.

**Discussion**

Eggs were observed to hatch directly into juvenile stages, as reported by Cumberlidge, (1999) for freshwater crabs, and Gross and Kaus, (2005) also reported that female crab was found with egg and hatchling in their abdominal pleopods showing early care for their offspring which is a modification for adaption in freshwater habitat (Cumberlidge, 1999).

It was observed that females mostly reside in their holes, taking care of their un-hatched eggs and young ones especially in the wet season while males are found outside, searching for food and mating. This result agrees with Lawal-Are, (2009) who reported more female crabs' occurrence than males during the wet season in Lekki Lagoon and Badagry with a ratio of 1:2 and also with the report of Bello-Olusoji *et al*., (2010)

 

that there are more female crabs than male in Abule Akure. The percentage of male crab seen at the study area is good for reproduction and this agrees with Arana, (2000).

The result of *S. africanus* with average egg of 250 agrees with the report of Cumberlidge and Sachs (1991) that a typical freshwater crab will carry up to 500 eggs around 1mm in diameter

Disney (1971) on *Plathythelphusa* in lake Tanganyika, reported average egg size recorded was 1.5-1.9mm in diameter similar to Cumberlidge, (1999) that newly laid eggs of freshwater crabs react 1.5mm in diameter carried in the abdominal brood pouch for brooding and hatchlings unlike the blue crabs *C. sapidus* that lay several thousand to a million eggs in high salinity water and develop into juvenile with average diameter of 0.25-0.35mm (Sharov *et al*., 2003).

Ng, (1988), reported that the deposition of the yolk in female takes place mostly in April–June with most of the eggs reaching maturity at the end of June, while the main brooding season is from June to October although breeding can occur all year round in agreement with *S. africanus* at Asejire reservoir where female crabs were observed carrying eggs mostly in the wet season showing that Males have sperm available for mating throughout the year.

The present result is incomparable with Carsen *et al*., (1996) that sexual maturity occurs at 40–50mm carapace length in female *P. patagonicus*. This indicates that *Platyxanthus patagonicus* reach maturity at early sizes than *S. africanus* which is a freshwater crab. Also various factors may be responsible for the differences in parameters of length-weight relationships in different seasons and species. Sparre (1992) stated that this may be due to temperature, salinity, food (quantity and quality), sex and maturity stage The correlation co-efficient (r= 0.069) of the length–weight relation was very high, indicating that changes in total length and weight of the crabs were proportional, in agreement with an earlier report of Younger (1985). Some other factors such as food availability, sex and season may contribute to the variation in weight of the samples. During wet and dry season, the crabs showed a slight increase in the total length and weight especially during the wet seasons.

A comparison of the weight range of *S. africanus* and *C. sapidus* shows that *S. africanus* have a low weight range compared to other crabs. According to Bello-Olusoji *et al.*, (2006), the weight of adult Portunid crabs (*C. palidus*) is greater than that of *S. africanus*. The results show that marine crabs are bigger than *S. africanus* freshwater crabs.

Study of Portunid crabs *C. pallidus* from the gulf of Guinea (Stickney, 1972) and *S. africanus* result of Bello-Olusoji *et al*., 2010 is similar to results observed on *S. africanus* that there was a positive correlation between the fecundity and weight of gravid crabs. Crabs with bigger sizes carry more eggs and those with smaller sizes can carry low number of eggs because fecundity seem to depend on the length and weight of the crabs. The relationship between fecundity and female size has shown a potential trend.

The five gonadal developmental stages of *S. africanus* observed show large eggs and different yolk colour change at each developmental stages in correlation with the result of Ng, (1988), that eggs of freshwater crabs are large with orange colour yolk. and it hatch directly into young crab.

The change in colour of egg in *S. africanus* freshwater crabs from green to yellow and to orange to brown and finally off white are similar to those described by Guillory and Hines (1997). Bardarch, *et al.,* (1972). also reported that the newly laid eggs of African freshwater crabs have bright orange colour and change slowly to dull brown, dirty grey and then to black before they finally hatch into a tiny larva (zoea).

The number of eggs brood by *S. africanus* is very small compare with hermit crab *Diogenes pugilator* which can brood 900 and 2838 eggs depending on the size of the female (Manjon-Cabeza and Garcia- Raso, 2000). The number of eggs per brood is determined by the size of the species at maturity. The large *P. armata* may carry up to 900 eggs whereas the marine crabs may produce hundred of thousand of much smaller eggs. Brood sizes are small because of the parental care shown by freshwater species. Eggs and hatchlings are cared by the female in her abdominal brood pouch until they are large enough to fend for themselves. Gardner, (1995) reports a female *Sudanonautes orthoslis* with a carpace length of 24mm captured in the process of releasing her brood up to thirteen juveniles each 3.5mm CW were found in her brood. A problem noticed affecting the rate of eggs laid by *S. africanus* was also reported by Cumberlidge, (1991). In a specimen of *S .africanus* captured with carapace length 81mm carry 261 eggs with a chamber not tightly sealed and several juveniles were escaping through the opening . This observation is similar to what obtained in *S. africanus* females carrying eggs loses some when moving fast.

Majority of the females collected during the wet season were incubating eggs. This suggests that spawning and hatching take place more during the wet season and all the crabs with eggs weigh more than those without eggs which cause an increased weight and length. The Mortality report of *S. africanus* at Asejire was in agreement with Cumberlidge, (2002) that mortality of *S. africanus* in the natural habit could be due to harsh season, old age, predators and pollution from the environment. All true freshwater 1crabs complete their entire life cycles in fresh water or terrestrial habitats and never enter the sea at any stage of their life (in fact, they actively avoid salt water environments) (Cumberlidge, 2008). This option is possible in true freshwater crabs because their reproductive strategy is modified so that their embryos hatch directly to produce juvenile crabs. It

 

has been shown that in true freshwater crabs all of the normal brachyuran larval stages (e.g. nauplius, zoea, megalopa) are passed through during a lengthy embryonic development within the egg resulting in young hatchling crabs emerging directly out of mature eggs ( Wu et al., 2010). This strategy adopted by freshwater crabs replaces that used by the majority of marine crabs, in which eggs hatch in seawater and release a free-living aquatic larva that metamorphoses while floating in the plankton.

The evolution of fluid-filled waterproof egg cases, however, has allowed direct development to take place in the true freshwater crabs and has freed them from having to return to the sea to complete their life cycle.

**REFERENCES**

Abdallah A.H, C.Elinge, M.M Graw, B. Hensen, K. Kamoga, M. Kuria, A. Leonharts, B.P Matembis, Nuhu.D, Oduro and M. Yonas, (2004): Comparative studies on the structure of an upland Africa stream ecosystem, Journal of Freshwater Forum 21: 101-130.

Adebisi A. A (1981): The physicochemical hydrology of a tropical seasonal river–upper Ogun River, 79:157-165.

Adeyeye E.I, (2008): Amino acid composition of whole body, flesh and exoskeleton of female common West Africa freshwater crab (Sudanonautes africanus) International. Journal Food Science Nutrition, 59: 669-705.

Edwards A. Milne (1886): Revision of the genus and description of Thelphusa quelgues species partic Novels by the collection of the museum's new Archives Histories nuturelle a Museum, Paris 5: 161-191.

Anetekhai, M.A .(1997): Molting, meristics and morphometrics in the African river prawn (Macrobrachium vollenhovenii, Herklots, 1857) from Asejire Lake, Oyo State Nigeria, Journal of Prospects in Science I:54-57.

Atar H.H and S. Sever, .(2003):Width Length-Weight relationship of blue crab, Callinectessapidus (Rathburn, 1896) population living in Beymelek lagoon lake Turkey Journal Vet. Animal Science 443-447.

Bagenal T.B (1978): Methods of Assessment of fish production in freshwater.3rd Edition.IBP Handbook N 3Pp 126-130, 166-167

Bardach J.E, Ryther J.H and W.D, Mclarney (1987): Aquaculture, the farming husbandry of freshwater and marine organisms. Willey-Interscience, Toronto U.S.A pp14:159-165.

Baliao D.D, E. M.Rodriguez and D.D, Gerochi (1981): Culture of the mud crab Sylla serrata (forskal) at different stocking densities Journal of Vol pg.

Barea L and O. Defeo. (1986): Appearance of red Delcangrejo presqueria (Geryon quinqiedena) in the world of fishing co Argentine-Uruguayan publ. com. Tec Mix. Fr Mark, 1 (1): 38-46.

Bayliss J. (2002): The East Usambara tree hole crab (Brachyura: Potamoidae) a striking example of crustacean adaption in closed canopy forest, Tanzania. African Journal of Ecology 40: 26-34.

Bello-Olusoji O.A (2004): Ecology and aquacultural potentials of two commercially important freshwater prawns in Nigeria Journal Applied Science, 7: 4479-4483.

Bello–Olusoji O.A, (2007): Assessment of the African river prawn. Macrobracium vollenhovenni (Hecklots1857)in some lentic and lotic environment in Nigeria African Journal Ecology,35: 80-81.

Bello-Olusoji O.A, Oyekanmi. M, Afunmiso O.M, Ozorewor. N, and M.O Bankole (2006):Length-weight relationship and stomach content of portunid crabs, callinecte pallidus (de-Rochebune, 1983) from the Gulf of Guinea Bowen Journal of Agriculture 3(1):65-72.

Bello-Olusoji O.A, M.O Afunmiso and M.O Bankole ( 2007): Some aspects of the feeding habits of commercially important penaeids from part of FAO fishing Zone 34 Journal of Niger Delta 5(20):124-136.

Bello-Olusoji O.A, O.J Anifowose and M.Y Sodamola, (2010): Length–Weight Relationships, Condition Factor and Fecundity of the West Africa freshwater crab, Sudanonautes africanus (Miline- Edwards 1883), in Western Nigeria from West African Journal of Applied Ecology 16:65-74.

Bologna P.A and Heck K.L (2002):Differential predation and growth rates of bay scallops within a sea grass habitat. Journal of Experimental Marine Biology and Ecology 299-314.

Bott R. (1955): The Sudanonautes africanus (Crust, Decapoda) and the royal of Congo Series..3:295-306.

Boyd C.E (1979): Water quality in warm water fishponds Auburn University Agricultural Experiment Station, Auburn University, 1st Eds, Craftmaster Printers, Alabama. 355pp

Buchanan B.A (1999): Distributional patterns of blue crabs (Callinectes sp) in a tropical estuarine Lagoon .Estuaries 11: 231-239.

Buttler J,R and B.E, Marshall (1996): Resource use within the crab–eating guild of the upper Kairezi River, Zimbabwe. Journal of Tropical Ecology 12, 473-490.

Cart, P.O and R.P Secreten S (1992): Presence In the Basin of Lake Albert (Uganda), the Upper Miocene of Potamonautidae (Acanthothelphusis) niloticus (Crustacean, Brachyura). Journal of the Academia of Sciences, Paris, series 314: 411-417.

Carsen E.A, Kleiman. S and Marcelo A.S (1996): Fecundity and relative growth of the crab, Platyxanthus

 

potagonicus (Brachyura :Platyxanthidae). In Patagonia Argentina Journal of Crustacean Biology.16:748-753.

Centell, M.A (1980): On the terrestrial behavior of the freshwater crab Potamonautes choloensis (Chace). Nyala 6: 95-107.

Chen J.C (1990): Growth, reproduction and population structure of the freshwater Sinopotamon yangtekiense Bott, 1967, from Zhejiang, China. Chinese Journal of Oceanology and Limnology 12: 84-90.

Cumberlidge. N (1985): Potamonautes (Platypotamoanautes) ecorssei (Marchand, 1902) (Decapoda, potamonautidae) new to Ghana and Northern Nigeria. African Journal of Ecology, 23; 195-197.

Cumberlidge, N (1986): Ventilation of the branchial chambers in the amphibious West African freshwater crab, Sudanonautes (Convexonautes) aubryi mondi (Balss, 1929) (Brachyura, Potamonautidae). Hydrobiologia 134, 53-65.

Cumberlidge N (1993): Two new species of potamonesmus Cumberlidge and Clark, 1992 (Brachyura, Potamoidea, potamonautidea) from the rain forest of west African. Journal of Crustacean Biology 13(3), 571-584

Cumberlidge. N (1994): Louisea, a new genus of freshwater crab (Brachyura: Potamoidea: potamonautidae, for Globonantees macropus edeaensis Bott, 1969 from Cameroon. Biological Society of Africa 107, 12-131.

Cumberlidge , N (1999): Modification of the fresh water crabs of west Africa family potamononatidae IRD Pg 1-38. Cumberlidge, N (1991): The freshwater crabs from Liberia (Gecarcinucoidae, Gercaricinudae) Crustaceana 61 (1):55-90.

Cumberlidge, N (1991): The respiratory system of Globanoutes macrpus (Rathbun, 1898), a Terrestrial freshwater crab from Liberia (Gecarcinucoidea, Gercarcinudae) Crustaceana 60 (4), 29-40.

Cumberlidge, N (2002): The freshwater crabs of Madagascar (Crustacea; Decapoda:Potamiodea) Zoosystema 24(1): 41-79.

Cumberlidge N.(2002): A new genus and new species of freshwater crab (Potamondea, potamondae) from Socotra Island, Yemen Journal of Natural History 38, 51-64.

Cumberlidge, N and R Sachs. (1989): From Liberia a new second intermediate host of Paragonimus uterobilaterials. Tropical medicine and parasitology 42, 73-74.

Cumberlidge, N and R. Sachs (1989a) A new second intermediate host of paragonimus interbilaterial in Liberia. Tropical medicine and parasitology 41: 435-436

Cumberlidge, N and R.Sachs. (1990): Distribution of metacercariae in freshwater crabs' relation to paragonimus infection of children in Liberia. Annals of tropical medicine and parasitology, 84(3): 277-280.

Cumberlidge, N, Sternberg, R.V, Bill.I.R and Martin, H. (1999): A revision of the genus Platyhelphus A. Miline-Edwards, 1889 from lake Tangayika, East Africa (Decapoda:Potamoidea: platythelphusidae) Journal of Natural History 33, 1487-1512.

Cumberlidge, N and Sachs .R (1991): The dwarf river crab Liberonautes latidactylus nanoides a Intermediate host of Paragonicus interbilaterals in Liberia. Tropical medicine and parasitology 41:435-436.

Cumberlidge, N , Boyko, ,C..B and Harvey, A.W (2002): A new genus and species of freshwater crab (Decapoda, Crustacea,Potamoidea) from northern Madagascar, and a second new species associated with Pandanus leaf axils. Journal of Natural History 36 (1): 65-77.

Cumberlidge N and Vannini M (2004): A new species of tree hole living freshwater crab (Brachyura: Potamoidea : Potamonautidae) from coastal East African. Journal of Natural History, 38:681-693.

Cumberlidge N. (2008): Insular species of afro tropical freshwater crabs (Crustacea; Decapoda: Brachyura: Potamonautidea and Potamidae) with special reference to Madagascar and the Seychellles. Journal of Zoology 77-71-81.

Cumberlidge N, and Ng PKL.(2009): Systematics, evolution and biogeography of the freshwater Crabs. Pp491-504 in Martin J.W, Crandall K.A, Felder D, eds. Crustacean Issues: Decapoda Crustacean Phylogenetics. Leiden; CRC.

Daniels S.R, Stewart B.A, and M.Y Gilbbson (1998): New (Brachyura, Potamonautidae). Cryptic species of river crab from the Olifanin river system *Journal of South African Crustacean* 71(8): 885-903.

Daniels S.R (2001): Allometric growth, hardness and morphological variation in Potamonautes Warreni (Calmen, 1908) (Decapoda, Brachyura, Potamonautidae) with a redescription of the species . Crustaceana, 74(3): 237-253.

Daniels S.R, Govws .G, Stewart B.A and M. Coke. (2002): Molecular and morphometric data Demonstrate in the presence of crytic lineages among freshwater crabs (Decapoda, Potamonautadae; Potamonautes) from the Drakensberg Mountains, South Africa, Biol *Journal of human society* .2002:78:129-147.

Disney, R.H.L (1991): Notes on Simulum ovazzae Grenier and Mouchet (Diptera; Simuliidae) and river crabs (Malacostraca: Potamidae) and their association *Journal* of *Natural History* 5, 677-689.

 

Dark M.E, T.G Wolcott, D.L Wolcott and A Httines (1998): Intraspecific intereference among foraging blue crabs C*allinectes sapidus* interactive effects of predator density and prey patch distribution. *Journal of Marine Ecology Progressive* Series 178:69-78.

Egborge A.B.M (1994): Observations on the diurnal changes in some physicochemical variables of lake Asejire, a new impoundment in Nigeria Pol. *Arch. Hydrobiloogy.* 26 (2): 61-73.

Food and Agriculture Organization FAO (1990): FAO Year Book Fisheries Statistics capture production *FAO* Rome 6, 86/1

Food and Agriculture Organization FAO (2002): Cultural Aquatic Species Information Programme provided by Inland Water Resources and Aquaculture Service A:/culture specie cultural aquatic species information programme. *Ericoleir sinensis 3Pp 342-351*

Food and Agriculture Organization FAO (2006): Fisher,W.G Bianchi and W.B Scot (eds). FAO Species Identification, sheets for purposes Eastern central Atlantic, Rome fishing areas 34,47 ( in part ). Vols7 Pp 713-720.

Francis. O and O. O Enakeme. (2007): Notes on the biology and ecology of *Sudanonautes floweri* (DEMAN,1901;Crustacea:Brachyura: Potamoidea: Potamonautidae) in river Ogbomwen, Southern Nigeria *Acta* boil. Colombia, 13 (1) 65-78.

Gardner, C (1995): Maturation in the male giant crab, *Pseudocarinus gigas*, and the potential for sperm limitation in the Tasmaninan fishery. *Freshwater Res*, 53: 661-667.

Grimes, B.G, M.T Huish, J.H Kerby and D. Morgan (1989): Species profile life histories and Environmental requirement of marsh crab. US fish and wildlife service Biol. Rep 82 (11:14) US Army corps of Engineers,TR.EL-82-4 18pp,1989.

Gherardi, F, Guidi.S and M. Vannini (1987): Behavioral ecology of the freshwater crab,Potamon *Fluviatile* Preliminary observation. *Investigacion Pesquera*, 51, 389-402.

Govws.G and B..A Stewart, (2001): Potamonautide river crabs (Depoda, Brachuyra, Potamonautidae of Kwazulu- Natal, South Africa. 27, 85-98.

Gross M, and S. Kaus. (2005): Upper Miocene freshwater crabs from the Northwestern magin of the styrian Brain(Brachyura. Potamoidea) *Ber Inst KF Uni Graz*. 10:21-23.

Guillory V.H and S. Hein. (1997): Sexual maturity in blue crabs, *Callinectes spadius* Proceedings Coastal Fishing Louisianas blue crab resource La.St University Academy of Science, 59: 5-7.

Guillory V.H, Perry M and S .Vanderkooy (2000): The blue crabs fishery of the gulf of Mexico United states a. Regional management plan ( States Marine Fisheries Commission Pp290-346

Guillory V .H (2001): Blue crabs homepage.*http a//www*.blue crabs.*net*

Guillory V.H (1996): A management profile of the blue crab, *Callinectes sapidus* L.A. Dept. of wildlife. Fish mgt. Plan ser.8 (2): 34pp.

Guillory V, Prejean. E, Bourgeois. M, Buro, J and J. Merrell, (2000):A biological And fisheries profile of the blue *crab, Callinectes sapidus. L.A Dept .Wildl. fis mgt. plan* ser.8(1):210pp

Hall N.G, K.D Smith, S. D Lestang and I.C Potter (2006): Does the largest chela of the males of three crab species undergo an allometric change that can be used to determine morphometric maturity? *ICES J. Mar.Sci*, 63: 140-150

Harper D.M, Mavuti. K.M and Muchurimucai.S. (1990): Ecology and management of lake Naivasha, Kenya, in relation to climate change, alien species induction and agricultural development *Environmental Conservation* **17**, 328-336.

Haynes E.K, Watson F..J and D.J,Hopson. (1976): Relation of number of eggs and egg length to carapace width in the brachyuran crabs. *Chinoectes baindi* and C. *spilis* from the south –eastern Bering sea and C *.salis* from gulf of Saint Lawence *.J. Fish Res*. *Bd* Can 33;2592-2595.

Hick,K.L, (1985): Post settlement mortality of juvenile blue crabs pattern and process : In Proceedings. Blue Crab Mortality Symposium, Gulf States. Marine fisheries Commission Publication 90. Ocean spring, Mississippi.

Hill. M.P and J.H O'Keefe (1999): Some aspects of the ecology of the freshwater crab (Potamonautes perlatus, Miline Edawrds) in the upper reaches of the Buffalo River, eastern Cape Province, South Africa. *South African Journal of Aquatic Sciences* 18, 42-50.

Hine A.H, J. Freire, T.G. Ruiz and D.L Wolcott (1990): population dynamics and habitat partitioning on foraging impact of crabs in a subesturay of Chesapeake Bay. The crustacean society summer meeting June 1-5, 1990. Wiliamsburg, Virginia

Imran. A and O.A Lam. (2008): Robust judgment of inter – object distance by an arthropoda, *Nature* 421,160-163.

IUCN (2004): Red list of threatened species. International union for the Conservation of Nature and Natural resources www.redlist.org.

Jensen, O.P and T.J , Miller (2005): Geostatistical analysis of the abundance and winter distribution patterns of

 

the blue crab *Callinectes sapidus* in chesapeake bay transactions of the Americans Fisheries Society 134: 1582-15

Kennan .C.P, J.P Dave and D.I Mann (1998): A revision of the genus *scyalla* Dettann 1833(crustacean,Decapoda *Brachyura portunidea* ) *Raffles Bulletin* of *Zoology* 46; 217-245.

King .M. K.(1998): Fisheries Biology Assessment and Management Copyright 1995 by Fishing News Books, Oxford. A division of Blackwell science Ltd Reprinted 1998. Pp24, 36-39.

Knorr D. (1985): Dye binding properties of chitin and chitosan, *Journal Food Science*, 48:36-38.

Kuhlmann, M.L and A.H Hines, (2005): Density–dependent predation by blue crabs in Natural prey population of infaunal bivalues: Experimental tests and behavioral mechanisms. *Marine Ecology Progress series* 215: 215-230

Lawal –Are .A.O (2009): Food and Feeding Habits of the Blue crabs, *Callinectes amnicola* (de Rocheburne) from three different interconnecting lagoons in south- west , Nigeria. *European Journal of scientific Research* l32: 88-94.

Lee S.L (2000): Zonation and heat tolerance of three Littornid gastropods on the rocky shore of Tanjung chek jawa, Singapore the *Raffles Bulletin of Zoology*. 57(2): 551-560.

Liu H.C and A.H Li (2000)*:* Reproduction in the freshwater crab *Candidiopotamon rathbunane* (Brachyura: potamidae) in Taiwan *Journal* of *Crustacean Biology* 20: 89-99.

Lim S.S.L and C.H Tan (2008): Burrow morphology characters of the fodder crab Community (Una *annulipes* H. Milines Edward, 1837) and ecological correlates in a lagoon *Crustaceans* 76 (9): 1055-1069.

Lopez- Abellan L.J.E, Balguerias and V. Fernandez-Vergaz (2002): Life history of the deep sea crab *Chaceon affinis* population off Tenerife (Canary island ). *Fish. Res*, 58: 23-239.

Manjon-Carbeza M.E, and J. F Garcia- Raso (2000 ): Reproductive aspects of females of the hermit crab, *Diogeness pugilator* (Crustacea.Decapoda); Anonura from Spain *Abstract* pp.85-93.

Mc Conaugha J.R and C.L Mc Conaugha (1996): Tag recapture study of the spawning stock of Chesapeake Bay blue crabs final Report for NDAA contact NA 89EA – H000060. November 1986 to October 1991. NDAA/NMFS, State Federal Relations Branch, one Black burn Drive .Gloucester, Massachuestts.45p.

Meye J.A, Arimoro F.O and C.A Edokpayi, (2003): Observation on some aspects of the biology of *Sudanonautes*. *aubryi* (H. Milne Edwards, 1886) Orogodo River, Niger Delta, Nigeria. *Tropical. Fresh Boil*. 2003; 12/13: 105-118.

Millikin M.R and A.B Williams (1980): Synopsis of biological data on the blue crab *Callinectes sapidus* Rathbun .FAO Fisheries Synopsis no 138 NOAA Technical Report NMFE ,38-51P

Monod. A (1988): Evolution of crustaceans and Bio-geographic thermosbenaces weekly reports of the meetings of Aacedamie of Science, series 3, 307: 341-348. Hebdomadaires des séances de l Aacedamie des science, series 3; 307: 341-348.

Ng P.K.L (1988): Reproduction in the freshwater crabs *Candidi opotamon* Rathbunae ( Brachyura: potamidae) in Taiwan Hung-chang, Liu and Chia-weili *Journal of Crustacean Biology* 20(1): 69-99.

Ng P.K.L, Stewick, Z and G. Pretzmann, (1995): A revision of the family *Deckenidae artmann*, 1897 (Crustacea: Decapoda: Brachyura; Potamoidae), with description of a new genus (*Gecarcanucidae*: *Gecarcinuoidea*) from the Seychelles, Indian Ocean. *Journal* of *Natural History* 29, 581-600.

Ng P.K.L and O. Naiyanter . (1995): The freshwater crab fauna (Crustacea: Decapoda: Brachyura) of the Philippines. IV on a collection of parathelhusidae from Bohol. *Proceedings Biological Society of Washington* 109(4): 695-706.

Nozais J.P, Docet, J. Dunan J and G Assale Ndri (1980): Paragonimiasis in the Black A figure About a score of recent outbreaks of worm Ivor. Bulletin of the society of pathologic exotic, 73 - 155-165.

Oesterling M .J (1991): Migration of blue crabs along floridas Gulf coast. Pages 37-57 in H.M Perry and W.A VanEngel (eds). Proceedings Blue crab colloquium Gulf states marine fisheries commission publication 7. Ocean springs Mississippi.

Okafor F.C (1988): The ecology of *Sudanonautes africanus* (A.Miline Edwards) (Crustacea;Decapoda) in Southeastern Nigeria. *Tropical Ecology*. 1988; 29:89-97.

Ogunleye I.K (1982): The structure and performance of fishermen at Asejire Dam (Oyo State) Southwestern Nigeria; *Advances in Environmental Biology*, 5(6): 1359-1363pp.

Pellegrin G.Jr. V. Guillory P. Prejean,H. Perry, J. Warren,P.Steele . T. Wagner and S. Heath (2001): Length – based estimates of total mortality for Gulf of Mexico blue crab pages 42- 49

Pinho,M.R, J.M, Goncalve, H.R .Matins and G.M Menezes,(2000) Some aspects of the biology of the deep – water, crab *Chaceon affinis* ( Miline–Edwards and Bovier, 1894) off the Azores Fish, Rese, 51: 283-295.

Prager M (1996): A simple model of blue crab *Callinectes sapidus*, spawning migration in cylla 54 Lake Bay. Bulletin of Marine Science 58: 421-428.

Pratt,A.E,Mclain,D.K and G,R. Lathrop (2003): The assessment game in sand fiddler crab contests for breeding

 

burrows. *Animal Behavior.*65, 945-955.

Purvea M.G, Kruuk H, Nel. J. and N. JAJ. (1994): Crab *Potamonautes perlatus* in the diet of otter *Aonyx capensis* and water mongoose *Atilax paludinosus* in a freshwater habitat in South Africa Zectshrift fur Saugetier kinde ;59:332-341.

Radhakrishan C.K (2006): The eggs of Marine –crab, An unexploited Resource Naga, the LELARM Quarterly Journal (vol23, no3) July to September,2004 Pp4 Inland fisheries resources of Nigeria CILA Occ. Paper FAO Rome.

Radhakrishan C.K (2000): The egg of marine crabs An- unexploited resources, ICLARM Quatrs, 23: 4-5.

Rosenberg, M.S (2001): The systematic and taxonomy of fiddler crabs a phylogeny of the genus Uca. *Journal of Crustacean Biology* 21:839-869.

Ruiz, G.M, A.H Hines and M.H Posey (1993): Shallow water as a refuge habit for fish and crustaceans in non-vegetated estuaries: An example from Chesapeake Bay. Marine Ecology Progress Series 99:1-16.

Sant Ana, R and P.Pezzuto. (2009): Sexual maturity of the deep-sea red crab *Chaceon notalis*, Manning and Holthuis, Latin American *Journal of Aquat. Res*., 37 (3): 429-442.

Schuwerack P.M, M. Lewis, J. W and P. Jone (2001): The potential use of the South- African river crab *potamonautes Warreni* as a bioindicator species for heavy metal contamination *Ecotoxicology* **10**, 159-166.

Seastedt, T.R (1984): The role of micro arthropod in mineralization processes A literature review on soil fertility investigation in Nigeria FPOD,EMAWRRD 1990 eds. Pp. 166.

Servicio Natural depesca 2008 (SERNAPESCA): Aunario estadisticode pesca http://www. Sernapesca. CL/ index. Php? Option =com- remostory and itemidand func= select and =2. Revised :30 March 2008.

Shahidi F, M.Chune and J. Synowiecki, (1999): Isolation and characterization of nutrient and value–added products from snow crab (Chionoecetes) processing discards *Journal of Agric and Food Chem.,* 39: 1527-1532.

Sharov A, Davis G, Davis B, Lipcius .R and R.M Montane. (2003): Estimation of abundance and Exploitation rates of blue crab (*Callinectes sapidus*) in Cheapeake Bay. Bull Mar Sci, 72:543-566

Shirley A.F, J.H,Volstad,G.R,D avis B.K Davis R.N Lipcius and M.M, Montane (1999): Abundance and exploitation rate of the blue crab (*callinetes sapidus*) in cheaspeake Bay. Bulletin of marine science 72;543-566.

Sparre P.(1992): Introduction to tropical fish stock assessment. Part 1 manual *FAO*, *Fisheries Technical Paper* 306/1.Rev,1992.Rome .

Sternberg R V and N. Cumberlidge (2001): Notes on the position of the true freshwater crabs within the brachyrhynchan. Eubrachyura (Crustacea: Decapoda: Brachyura). Hydribiologia 449:21-39.

Stickey R.R (1972): Length – weight relationship for several fishes and invertebrate in Georgia costal waters with condition factors for fish species. Skidaway Institute of Oceanography Savanna Georgia.

Sukumaran K.K and B. Neelekantan (1997): Length –Weight relationship in two marine portunid crabs, portunus *pelagicus sanguinolentus* (Herbs) and Portunus pelagicus(Linnaeus ) from kanataka coast Indian *Journal of Marine Science* 26.39-42.

Somers M.J and J.A.J Neil (1998): Dominance and population structure of freshwater crabs (Potamonanautes perlatus Miline Edwards) *South African Journal* of Zoology **33**, 31-36.

Synowiecki . J and N. A Al-Khateeb,(2003): Production properties and some new application of chitin and its derivatives. *Crit Rev Food Sci Nutr*, 43: 145-171.

Tabash F.A (2001): Assessment and Ecological characterization of the Blue crab (jaiba,*Callinectes arauatus*) in the Gulf of Nicoya, Costa Rica, www.una.ac.cr/biol/unalaw/english/crab. htm.

Trino A.T and C. Sarroza (1995): Effects of a diet lacking vitamin and mineral supplements on growth and survival of *Penaeous monodon* juveniles in a modified extensive culture system *Aquaculture* 136 : *23*-330

Trino. A.T, O.M Millsmena and C. Kennana (1999): Commercial evolution of mono sex pond culture of the mud crabs 55cylla species of three stocking densities in the Philippines *Aquaculture* 174: 109-118.

Van Engel W.A (1990): Factors affecting the distribution and abundance of the blue crab in chespeake Bay, pages 179-209 in S.K Majumdar L.W Hall and H.M Austin (eds).

Varricchio, O,David J, Martin A.J and K.Yoshihiro (2007): First trace and body fossil evidence of burrowing denning dinosaur In: Proceedings Royal Society Biologcial science 274(16): 1361-1368.

Walace M, (2000): North Atlantic oscillation / annular mode; two paradigms – one phenomenon quant. d. ray. meteo soc, 126; 701-806.

Williams M.J (1984): Seasonal abundance distribution and habitat selection of juvenile Callinectes sapidus (Rathbun) in the northern gulf of Mexico. *Journal of Experimental Marine Biology and Ecology* 137:165-183.

Wu H.X, Xue J Z and N Cumberlidge (2010): An extra embroyonic phase in the true freshwater crab

 

Sinopotamon yangtekiense Bott 1967 (Decapoda, potamidae). *Chinese Journal of Oceanology and Limology* 28;725-730.

Yeo, D.C.T, Ng P.K.L, N.Cumberlidge , C.Madaiheas,S.R, Daniels and M.R, Campos (2008): Global diversity of crabs (Crustacea: Decapoda:Brachyura) in freshwater. *Hydrobiologia* 595:275-286.

Younger A.Y.(1985):Distribution and abundance of ghost crabs, *ocypode* ceratophthalmus in relation to abiotic factors and human disturbance on Singapore beaches. Presented at the 21st Pacific Science Congress (June, 18-12-2007) Okinawa, Japan.

Zeil, J and J,Layne. (2002): Path integration in fiddler crabs and its relation to habit and social life in *Crustacean*. *Experimental systems in Neurobiology* (ed.K Wiese). pp227-246. Heidelberg springer Verlag.

WWW.Wikkipedia.com Alaska fish and wildlife news Alsaka Department of fish and game division of wildlife conservation (Retrieved 2007-6-6)

WWW.nmu.edu biology / Neil main Freshwater crabs.

Freshwater biology: www.nmu.edu/biology/neil/mainfwc- website/fwc biology- html-21k

www.blacksci.co.uk/fnk